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ABSTRACT

Initiated nine years ago by the University of Calgary Faculty of Education Computer Applications Unit in cooperation with the nearby Vocational and Rehabilitation Research Institute (VRRI), this project uses computer assisted instruction (CAI) to teach social and vocational skills to developmentally handicapped young adults, many of whom also have physical handicaps. The teaching of social arithmetic and reading has necessitated the use of multi-media terminals, and several such terminals have been developed and used: the current model, based upon a microprocessor, can be adapted to the needs of the individual learner through a variety of input and output devices. Principles derived from research on learning among the retarded have been used to design two program continua aimed at enabling trainees to acquire some of the social skills needed for independent living in the community. Special input devices enable the physically handicapped to communicate more easily with the computer, and "concept keyboards" assist the retarded by reducing the amount of mental recoding required. The success of this project, now an integral part of the VRRI program, is leading to further use of CAI at the institute and in other centers. (Author/BK)

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CAI FOR THE DEVELOPMENTALLY HANDICAPPED:

NINE YEARS OF PROGRESS

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ABSTRACT

A nine year project is described in which CAI has been used at an institute for retarded young adults, most of whom also have associated physical handicaps. The teaching of social arithmetic and reading has necessitated the use of multi-media terminals. Several such terminals have been developed and used, and details are given for the present model, which is based upon a micro-processor. Principles used in the design of courseware are derived from research on learning among the retarded. Two program continua have been developed, aimed at enabling the trainees to acquire some of the social skills needed for independent living in the community. These continua are described together with their associated management systems. Special input devices enable the physically handicapped to communicate more easily with the computer; and "concept keyboards" assist the retarded by reducing the amount of mental recoding required. The success of the project is leading to further use of CAI, both at the present institute and at other centres for the retarded. Requirements for further development of CAI for the retarded are discussed.

1. CAI AT AN INSTITUTE FOR THE DEVELOPMENTALLY HANDICAPPED

It is now nine years since a CAI project was initiated by the University of Calgary Faculty of Education Computer Applications Unit for teaching developmentally handicapped young adults. Originally a research venture in cooperation with the Vocational and Rehabilitation Research Institute (VRRI) on the edge of the University campus, this project has now become an integral part of the education offered by the Institute. Further, it is being progressively extended within the VRRI and its success has led to the establishment of CAI in other centres for developmentally handicapped persons. These include a school for the retarded, a children's hospital school, an institute for the severely handicapped, and a centre for less severely handicapped young persons.

The VRRI provides education and vocational training for approximately 250 developmentally handicapped persons: that is, persons who have mental handicap and also, for the most part, some form of associated physical handicap. The trainees' ages range from 16 to 50 years, although most are between 18 and 24 years. The majority may be classified as "trainable", although a few are "educable" and a few "dependent". Some trainees have cerebral palsy, and some are severely disturbed.

The objective of the Institute is to give training in social and vocational skills to the point where trainees are able to support themselves and live independently in the community. Part of this training takes place

in workshop units, and part in the Social Education Program; other units are concerned with pre-vocational training and assessment. All clients rotate through the Social Education Program, which accepts 170 of the trainees for approximately three month periods. Of this number, 100 are usually taking CAI lessons at any one time. For this purpose, seven multi-media terminals are in use on weekdays from 8.30 a.m. to 4.30 p.m., with each trainee having a half-hour session. The terminals are also used during certain hours in the evenings and at the weekend.

2. SPECIAL REQUIREMENTS

The environment in an institute for the developmentally handicapped determines the kind of CAI that is required. The subject matter taught must have immediate relevance to the needs of the trainees. Some of them have already passed through the regular schools, without learning many number or language skills. Others come directly to the Institute through referrals from other institutions. If these people are to support themselves in the community, they need to learn "survival skills" such as money handling, shopping, budgeting and simple reading. Further, the teaching materials must not use content taken from elementary school texts designed to meet the interests of children: they must be specifically designed to be appropriate for an adult population.

It follows that, when such CAI programs are evaluated, an important factor to be taken into account is the amount of transfer from the program to a real life situation.

In regard to CAI terminals, the environment at an institute such as the VRRI implies that a simple hard-copy or display type terminal is not adequate. To teach money handling and shopping skills it is essential to have high quality image projection in order to illustrate coins, bills, and items to be purchased. Most clients are unable to read and, although the use of simple and consistent routines can overcome many resulting problems, audio output is desirable. For learning to read it is obviously essential.

The conclusion is that CAI for the developmentally handicapped requires a terminal with multi-media output. For many trainees it is also more effective with a terminal which has special purpose input devices, while for those with severe physical handicaps such equipment is always required.

3. MULTI-MEDIA TERMINALS

The special requirements of CAI for the developmentally handicapped can not be met quickly and easily. They require a consistent effort over a period of years, with continuous evaluation and feedback aimed at improving the quality of both courseware and terminals.

The VRRI project began in 1971 with a single Teletype, using programs designed for elementary school level. None of the anticipated problems appeared. Those trainees chosen to participate initially had no difficulty in locating the keys on the keyboard: and there was no damage to equipment, nor has there been during all the nine years of the project. An unexpected

bonus was the high level of interest and motivation shown. Results were considerably better than expected, but it was apparent that many improvements could be made.

The Computer Applications Unit has always used a computer dedicated to CAI, with commercially available time-shared software. Initially this was a DEC TSS-8 system with 17 ports, but this was replaced in 1976 by a DEC PDP 11/70 system with 48 ports. Connection to such ports from the VRRI and other remote centres is via the ordinary telephone network. Therefore the use of several peripherals, attached to a standard hard-copy or display terminal to make it into a multi-media terminal, requires an interface between these devices and the modem.

The Unit developed an interface to control a Kodak random access carousel slide projector in 1969. Four such multi-media CAI terminals were installed in a trailer, which was located at the VRRI. The first money handling and shopping programs were used in this trailer with considerable success (Strain, 1974). When an extension to the VRRI building was completed in early 1976, the four multi-media terminals were therefore moved into a special CAI room and more terminals were installed. Not only was this much more convenient for use, it was now possible to use CAI for teaching the cerebral palsied trainees confined to wheelchairs, and others who were unable to climb the few steps into the trailer.

A prototype terminal developed by the National Research Council of Canada was introduced. This was a more complex multi-media terminal and had an interface which controlled, besides the hard-copy or display terminal,

a slide projector, a tape recorder for audio output, and an ultra-sonic touch sensitive display for input (Hlady, 1969). The latter proved to be a very effective and versatile input device.

Later, a commercial version of this multi-media terminal was also in operation for the reading programs. This had a cassette device for audio output, and a touch sensitive display using light emitting diodes and photosensitive transistors.

At the present time, almost all the CAI for the developmentally handicapped makes use of a microprocessor-based multi-media terminal developed in the Computer Applications Unit in 1978. Fifteen such terminals have been constructed. Each uses an 8080 chip, which has proven reliability, and as S-100 bus to provide flexibility. Depending upon the applications for which it is used, the terminal may have up to 56K bytes of RAM and 16K bytes of EPROM. The latter is used for storage of utility programs, and sometimes for synthetic speech data. The character generator provides 24 lines of 80 characters as standard, but can also give 12 lines of 40 double size characters. Prior to the introduction of these terminals it had been necessary to use a 23 inch monitor for work with the cerebral palsied, many of whom are partially sighted. It is now possible to use the large size characters on the 17 inch monitor which is a standard component of the terminal. A graphics board allows control of 240 X 256 points on the screen. A Computalker board is used to produce a limited amount of synthetic speech; and a board has been developed to control the Kodak random access carousel slide projector. This last board also has a jump-on-restart facility, so that it is not necessary for the micro-computer to have a front panel: it

is activated as a terminal when the power is switched on.

The microcomputer and slide projector are housed in a comparatively small box, the front of which forms a rearview screen. The monitor is placed in line with the screen, and the keyboard is placed in front. Special purpose input devices can be attached to the keyboard.

Using the maximum amount of RAM, and one or two floppy disks, the terminal becomes a stand-alone CAI computer capable of supporting all the programs in use for the developmentally handicapped. In this configuration, one terminal has been placed in a small town 80 miles from Calgary and has been used successfully in a project for the handicapped since August 1979.

4. DESIGN OF COURSEWARE

The most important sets of social survival skills needed by developmentally handicapped persons, when they have to support themselves in the community, relate first to money handling and secondly to reading. The curricula used to teach these two sets of skills at VRRI were therefore divided into units, each representing one subskill. These were then arranged in a linear and progressive sequence to form two continua, one for social arithmetic and one for reading. Within each continuum, a CAI program was developed for each unit which taught that subskill and tested it to criterion before the trainee was allowed to proceed to the next unit. The purpose was to form a carefully structured curriculum, divided into small learning steps arranged in a hierarchy and leading to the required survival skills.

The continuum of social arithmetic programs makes use of the microprocessor-based terminal. It begins with counting skills, and proceeds to simple addition, subtraction, and place value. This is followed by units on the recognition of coins and bills, more complex addition and subtraction, and problems relating to money. Later units are concerned with shopping and making change, keeping bank accounts, and budgeting. The eighty units are controlled by a management system which monitors each trainee's progress. A high passing criterion is set to ensure repetition of the units and thus achieve over-learning. The system allows the instructor to obtain reports on all trainees or on an individual trainee. If necessary, the instructor can override the management system to place a trainee at a more appropriate skill level.

The reading continuum makes use of both the microprocessor-based terminal and a commercial terminal referred to earlier. The first part of the continuum is concerned with recognition of shapes and letters. The second part consists of forty units, specially written to teach reading to young adults (Brown and Bookbinder, 1967). The earlier units are concerned with recognition and pronunciation of phonemes; these are then embedded in words; and in the later units sentences and paragraphs are introduced. All units make use of cassette-based audio under computer control, and each is followed by a test for which answers are entered using a touch sensitive display. They are arranged in a linear sequence but a management system routes a trainee to go forward three units, then drop back two. This ensures constant rehearsal of the skills which are learned.

The third part of the reading continuum consists of social sight

vocabulary programs which are used to teach recognition of common words such as "Telephone" and "Poison". Again, this requires use of a slide projector and, preferably, a small amount of audio (Holz, 1976).

Various programs for the developmentally handicapped are used to teach skills other than money handling and reading which are needed for daily living. These include programs to teach nutrition, time sense, laundry symbols, and filling in of forms, also a program to train cafeteria cashiers. The latter is the first of what is intended to be a set of programs relating to vocational skills.

Throughout the programs, didactic procedures are avoided and verbal instructions, either written or oral, are kept to a minimum. Insofar as possible, behaviour is "shaped" as one CAI program follows another.

Two important characteristics of the developmentally handicapped are a limited short term memory and an inability to attend to relevant cues. The programs are therefore designed to give frequent and immediate reinforcement in relatively consistent formats which can be easily recognized by the trainees, and repetition is used to achieve over-learning. When material for a new skill is presented, irrelevant stimuli are deleted. Following successful practice of the skill, a wide range of stimuli are shown in order to facilitate generalization to a real life situation. For example, when teaching the words "No Trespassing", a slide is first presented which shows only these two words. When they have been mastered, other slides present the words in context, on a sign standing in a field.

Provided that the continua contain carefully sequenced programs which

ensure success and the teaching materials relate to adult interests, motivation of developmentally handicapped persons taking CAI programs is not a problem. Indeed, all the evidence indicates that attention span increases substantially when they use a computer terminal: trainees at the VRRI enjoy their CAI sessions.

5. SPECIAL INPUT DEVICES

Special input devices have been developed in the Computer Applications Unit in order to enable more handicapped persons to access the CAI programs, and also to make such programs more effective. The special devices may therefore be classified into two types: those which allow a trainee to overcome a physical handicap, and those which simplify the mental operations required to interact with the program.

Devices of the former types have frequently been developed for use by the cerebral palsied trainees at the VRRI. A computer terminal interface for POSSUM apparatus was produced several years ago and has been described elsewhere (Hallworth and Brebner, 1979). This consists of an indicator board on which a light may be moved using any binary control such as a handswitch or a footswitch, or a mouthpiece on which the user can suck and puff. When the light has been positioned in the square of the required character, this is entered into the computer using the same control apparatus. A POSSUM Expanded Keyboard may be used by trainees who do not have the strength or motor precision to operate a standard keyboard. Mention has already been made of two touch sensitive displays which have proved to be very effective input devices. The microprocessor-based terminal

incorporates an inexpensive light pen which appears potentially useful to some handicapped persons.

In effect, there has so far been only one VRRI trainee who was unable to use a CAI terminal due to physical handicap, and he suffered from multiple handicaps including extremely poor vision.

The special input devices intended to simplify the mental operations required to interact with the CAI programs all perform essentially the same function: they reduce the amount of recoding required by the user.

The touch sensitive displays achieve this by allowing the handicapped person to point, with his finger or a stylus, at an image projected on to the screen or a word displayed on the CRT. In either case, there is no necessity to recode the image or word into the symbols shown on the standard keyboard. With persons who have a limited short term memory, this can be a decided advantage.

Special purpose keyboards which can be attached to the microprocessor-based terminal achieve the same effect by presenting to the handicapped person the images or codes which are required to be learned. For example, a "money keyboard" is used with some of the social arithmetic programs on which the keys are actual bills and coins: no other keys are included except RETURN and DELETE. For the program to teach laundry symbols, a keyboard is used on which the keys are the symbols to be learned, again with only RETURN and DELETE, in addition. For use with the program to teach a sense of time there is a keyboard with three keys only, representing "Early", "On Time", and "Late"; and for use with the nutrition program, a

special keyboard has keys with illustrations of the major food groups. For the program to train handicapped persons as cafeteria cashiers, a cash register has been converted into a computer terminal by using pieces of bubble-pad keyboard in place of the usual keys. Similar material may be used to teach Bliss symbols.

It is a difficult task for a handicapped person to recode stimuli into numbers or letters, and perform further mental operations on such symbols before taking overt action to answer the question in a CAI program. When the objective is to teach social arithmetic skills such recoding may be quite unnecessary, and may indeed inhibit the required learning. Special purpose keyboards, sometimes referred to as "concept" keyboards, can alleviate this problem.

6. RESULTS

Numerous studies relating to different CAI programs used with developmentally handicapped persons have already demonstrated that they are effective (e.g. Sandals, 1973; Strain, 1974; Eaton, 1975; Holz, 1976; England, 1979). Moreover, it should be noted that most of these studies have used a "transfer test", to ensure that the skills learned are not merely related to material presented through a CAI terminal, but are transferable to real life situations. Direct observation of individual trainees has indicated that there are sometimes dramatic improvements in rate of learning. The unanticipated benefit of increased attention span has already been mentioned. There is also an improved attitude to other types of learning.

For these reasons, CAI has become an integral part of the Social Education Program at the VRRI. It is gradually extending into other units at the Institute, and into other institutions for the handicapped. Further, with the progressive reduction in hardware costs, CAI is already so much less expensive than traditional instruction that it is easily justified as a tool for teachers of the handicapped.

It is only too apparent, however, that much work remains to be done. There is an urgent need for better quality and more reliable audio, therefore work is in progress in the Computer Applications Unit on the use of digitizei speech. With the advent of low cost eight-inch Winchester disks, this may soon be economically feasible. Hopefully, in the near future the use of videodiscs will lead to more effective audio and video, and also allow much needed movie sequences.

The major problem will therefore lie in the area of courseware. If present experience is any guide, a considerable amount of research and development work will be required over a period of many years before we have available, for developmentally handicapped persons, CAI programs which are as effective as we believe they should be.

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TITLE / *TITRE* RESEARCH AND PRACTICE IN CAI FOR THE DEVELOPMENTALLY HANDICAPPED

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1. RESEARCH AND PRACTICE: THE PROBLEM

The transition from research to practice in CAI is difficult to achieve. Ample evidence to this effect is provided by the many CAI projects which have appeared, only to disappear again without trace; also, by the many researches which have as yet led to no identifiable application.

It is also difficult to determine at what point research has passed into practice.

However, when a project has been in existence for a number of years, when it has passed through progressive stages of development in both courseware and hardware, and when it now forms the basis of a substantial part of the instruction supplied in an institution, it may reasonably be claimed that research has indeed passed into the stage of practice.

This is the situation at the Vocational and Rehabilitation Research Institute (VRRI) in Calgary, where a nine-year project of research relating to CAI for developmentally handicapped young adults has now for an extended period of time provided the basis of the Social Education Program.

The early stages of the VRRI project were reported at the Second Canadian Symposium on Instructional Technology (Brebner and Hallworth, 1976). The Institute provides training for 250 adults, most of whom are aged from 18 to 24 years, although the range is from 16 to 50 years. All are developmentally handicapped: that is, most have moderate to severe retardation, generally with some associated physical handicap. Some trainees are emotionally disturbed and some have cerebral palsy.

The primary purpose of the Institute is to provide the trainees with the skills necessary to enable them to become self-supporting members of the community. However, another purpose is to engage in continuous research with a view to finding more effective training procedures. In other

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words, the Institute was established to engage in both research and practice and, particularly, to attempt to facilitate the transfer from one to the other. This latter objective was considered particularly important because, as in the case of CAI, the history of work in the field of mental retardation illustrates the difficulty of conducting research which is relevant to practice, and of then bringing that research into practical applications. The Institute itself is therefore to be regarded as a project aimed at relating the two.

The courseware now provided in this project is based upon research in a number of areas. These include laboratory studies of learning among the retarded; the design and evaluation of CAI programs for the developmentally handicapped; work on aspects of man-machine interaction relating to handicapped users of CAI, including multi-media terminals and specialized input devices; and evaluations of the transfer of such learning to "real life" situations.

This research has been progressively applied in a practical situation. The Social Education Program at the VRRI accepts 170 trainees at a time, drawn from the different Vocational Units within the Institute, also from the Pre-Vocational Unit and the Perceptual and Motor Training Unit. Of this number, 100 are at any one period taking CAI courses on the seven multi-media terminals now operating in a special purpose room at the Institute.

These terminals are attached to a DEC 11/70 computer in the Computer Applications Unit at the University, using direct telephone lines and hardwired modems. They are in use from 8.30 a.m. to 4.30 p.m. on weekdays, trainees having half-hour sessions. The terminals are also used in the evenings and at weekends.

2. RESEARCH AND LEARNING AMONG THE RETARDED

It is frequently claimed that the most effective CAI arises out of the requirements of subject area content rather than from any theory of learning. In the case of higher level learning, such as university physics or statistics, this may well be the case. Moreover, it may be readily acknowledged that very little in the way of CAI programs has been produced by those protagonists who several years ago were declaring that learning theory must necessarily be the foundation of computer-based education.

However, the answer to such claims may turn on what is understood by the term "learning theory". It should be noted that, since the work of Hull (1952), there have been comparatively few attempts among academic psychologists to develop all-encompassing theories of learning. Rather, work has concentrated upon particular aspects of learning which are susceptible to empirical verification. This is despite the fact that, in several branches of applied psychology, and perhaps especially in educational psychology, it still occasionally appears an acceptable ambition to account for all forms of learning by means of one eclectic description.

For the last 30 years, however, much of the research on learning among the retarded has had an empirical basis arising both from theory and from practical exigencies. Above all, this has demonstrated that mentally handicapped persons can be trained to support themselves and live independently in the community. Such work has been summarized by Gunzburg (1960), by O'Connor and Tizard (1956), by Clarke and Clarke (1965), and by many others. A comprehensive discussion of learning among the developmentally handicapped and the implications for teaching strategies is given in Brown and Hughson (1980).

A suggestion arising from such research is that, conceivably, developmentally handicapped persons could achieve part of their learning by means of CAI. This was the basis of the project described in the present paper. However, as CAI programs were developed, it was necessary to examine in more detail some of the findings relating to how such persons may be assisted to learn most easily and effectively.

Several principles were therefore used in the writing of the programs. One, for example, arises from the suggestion that the retarded commonly have a deficiency in short term memory. This mandates that programs be written so as to minimize the load on short term memory; for example, by ensuring immediate feedback so that the trainee does not lose track of the problem, providing cues such as counting devices on a CRT, or developing special input devices to minimize coding requirements.

Another research finding, related to the suggested deficiency in short term memory, is that many learning difficulties of the retarded arise from an inability to perceive and attend to relevant stimuli; and that, once it begins, the learning of the retarded is strictly comparable to that of other persons (Zeaman and House, 1963). This implies a need to use careful stimulus control in CAI programs for the developmentally handicapped, beginning in the early stages of learning with frames which present only the relevant stimuli, and progressing gradually to frames which include extraneous stimuli in order to facilitate generalization to real life conditions.

For all retarded subjects, overlearning is necessary in order to ensure retention. This involves a great deal of repetition, which is more easily achieved in a CAI program than by almost any other means.

Too many words confuse the handicapped person (Brown and Hughson, 1972), therefore the CAI programs should use a minimum of words, either displayed on a CRT or output by an audio device. One implication is that visual images should frequently be used instead of words. Another is that programs should not be didactic: rather, they should attempt to "shape" behavior.

A small amount of audio, on the other hand, may help the learning of words (Holz, 1976). However, for those who are unable to read, the use of a standard program format helps to establish habits of perceiving a display and making a response which make the use of words unnecessary.

Motivation is always important in learning, but especially so among the handicapped. Such persons have frequently experienced frustration in ordinary learning situations,

often accompanied by rejection and ridicule. It is therefore essential that they meet with immediate success and receive immediate reinforcement.

Considerations such as the above indicate the need for a well structured curriculum made up of small learning steps which have been carefully sequenced. The development of such a curriculum can with advantage make use of research on instructional objectives and task analysis (e.g. Resnick, 1976), the design of instructional sequences (e.g. Briggs, 1970), and criterion referenced tests (Popham, 1978).

Since developmentally handicapped persons are considered to have a deficiency in attention span and perceptual discrimination, it might have been expected that trainees at the VRRI would have difficulty finding the appropriate keys on a standard keyboard, and that their lack of attention to the CAI programs would result in poor learning. On the other hand, research evidence has suggested that these deficiencies do not appear when developmentally handicapped persons are working on meaningful material which is appropriate to their level of ability. There have been no problems of attention span in connection with the use of CAI programs, nor have there been any problems in selection of appropriate keys. Possibly because the programs contain meaningful material of appropriate difficulty level, and because the trainees are kept actively responding at the terminal, there appears to be an increased attention span that carries over to work elsewhere in the Institute. A similar generalization of positive attitudes is also noted.

The conclusion is that, given attention to what is already known with regard to learning among the developmentally handicapped, CAI programs can be written for them which can be used effectively, and which can also enhance understanding of their learning.

However, this is dependent upon the development of appropriate courseware and terminal devices.

3. COURSEWARE

A principle used in the selection of subject matter to be taught in the Social Education Program at the VRRI is that it must be relevant to the experiences and interests of the trainees, and lead to the acquisition of those "social survival skills" which they will need for daily life in the community.

An implication is that a standard school curriculum, as used for children of equivalent mental age to the trainees, is not appropriate for use in the Institute. "Social arithmetic" is needed which is centred upon money handling, shopping and, at higher levels, budgeting and the keeping of bank accounts. Reading must centre around topics relating to the lives of young adults. In most cases, it may be confined to the learning of a "social sight vocabulary" consisting of a limited number of words which are seen, for example on notices, in everyday life. Other appropriate skills relate to simple principles of nutrition, completing forms, telling the time, and developing a sense of time.

In view of the special learning needs of the developmentally handicapped, CAI is an appropriate technology to use in teaching skills such as the above. However, it was necessary to design and produce all CAI programs that were required. Further, the subject matter imposed special requirements: programs on money handling and shopping require projected images of coins, bills and items to be purchased; and programs on reading require audio output.

It was therefore necessary to use a multi-media terminal, with a CRT display, a slide projector under computer control and, for some purposes, an audio cassette under computer control. Large characters are used for trainees who are partially sighted, and special input devices are available for those with severe physical handicaps.

A linear hierarchy of social arithmetic skills has been implemented as a series of CAI programs. These begin with counting of boxes displayed on a CRT terminal and continue through simple addition and subtraction, place value, identification and counting of coins and bills, the making of simple purchases, keeping of bank accounts, and budgeting. A total of 80 programs are linked together by a management system which guides the trainee through the sequence, keeps student records, and produces reports for the instructor. An override option allows the instructor to replace a trainee who is experiencing undue difficulty, or one who requires further advancement.

Programs attempt to shape behavior by proceeding in very small steps and keeping the trainee active. All responses are recorded, and a program must be mastered to criterion before the management system moves the trainee to the next program in the hierarchy. Provision is made for considerable repetition to ensure frequent rehearsal and overlearning. Reinforcement is always immediate, and in a standard format which trainees can easily understand, as for example a large tick on the screen or a "beep" on the keyboard. Use is made of familiar procedures so that a trainee knows what to do from habit, without any necessity to read instructions. All images relate to a trainee's experience: bolts and washers from the vocational units are shown on slides used for teaching place value; toothpaste and bread are shown on slides used to teach purchasing.

The reading continuum is based upon the Clifton Audio-Visual Reading Programme developed by Brown and Bookbinder (1967) and uses a CRT, a slide projector and rearview screen, a touch sensitive overlay, and an audio cassette under computer control. The forty programs use a phonic approach, and each follows an identical format. The trainee is shown some letters or words, the corresponding sounds are given, and he is asked to speak these aloud. This is followed by a multiple choice test to determine which items he has learned.

The hierarchy of CAI programs is again linear, with an override option available to the instructor. Overlearning is achieved by repeating each program on three consecutive training sessions.

The programs for pre-reading skills and social sight vocabulary may be used with trainees not yet ready for reading. The former teaches letter recognition by means of a carefully graded series of steps (Eaton, 1975). The latter teaches specific words such as "NO TRESPASSING" by means of a set of slides arranged to provide graded stimulus control. The first slide shows the words alone, and the last one shows the words in context so that the learning will more easily generalize to the outside world (Holz, 1976).

4. MAN-MACHINE INTERACTION

The research and development relating to the above CAI courseware at the VRRI has necessitated parallel work on a specific aspect of man-machine interaction, namely the interaction between developmentally handicapped young adults and CAI terminals. This has two aspects: the design, development and experimental application of terminals with multi-media output on the one hand, and special purpose input devices on the other.

1. Multi-media Terminals

The need to use multi-media terminals for CAI with the developmentally handicapped has already been documented. Image projection is essential, audio output is desirable, large characters and graphics are useful.

The use of general-purpose time-sharing software obviates substantial development costs, but necessitates the use of an interface to control the various devices on a multi-media terminal. Throughout the twelve year history of the Calgary CAI project a variety of interfaces have been developed and used. These have been discussed in detail elsewhere (Hallworth and Brebner, 1979).

The multi-media terminal now in use was designed and developed in the Computer Applications Unit and is based upon a microcomputer. This uses an 8080 microprocessor, to obtain proven reliability and access to a substantial amount of software; and an S-100 bus, to ensure flexibility. It may hold up to 56K bytes of RAM and up to 16K bytes of EPROM, depending upon the requirements of the situation in which it is used. A character generator provides 24 lines of 80 characters, or 12 lines of 40 double size characters which are very suitable for partially sighted trainees. A graphics board gives control of 240 x 256 points on the seventeen-inch monitor, and facilitates the creation of special characters such as Bliss symbols. Phonetically coded speech may be stored in EPROM or on disk and output by a Computalker board; and boards are now being introduced to code and play back fully digitized speech in limited amounts which may be stored in RAM and possibly, at a later date, on an eight

inch Winchester disk. To obtain image projection, a board has been developed to control a Kodak carousel random access slide projector. Although it is somewhat cumbersome, there is no doubt that this slide projector is the most efficient and readily available means of obtaining computer controlled still images at the present time; and further, the images from 2 x 2 inch slides are superior to others currently used for CAI.

The complete microcomputer and slide projector are housed in a box, the front of which makes a frame for the 15 inch by 15 inch rearview screen. The CRT terminal is placed in line with the screen, whilst the keyboard and any special input devices are placed in front.

When a request was made to extend the CAI project to serve developmentally handicapped persons in Banff, some 80 miles from Calgary, it was found that the cost of connection by phone line was prohibitively expensive. A microcomputer-based terminal was therefore fitted with the maximum amount of RAM and two floppy disks. With the provision of relevant software, it was then a stand-alone computer capable of storing and delivering all CAI programs presently in use for the handicapped, and has operated successfully since August 1979.

Fifteen microcomputer-based terminals have now been constructed, and two of these are in use as stand-alones. Further upgrading, to use an 8086 chip and faster memory, is quite practicable; and time-shared software is already available for the stand-alones.

2. Special Input Devices

Special input devices may be attached to the microcomputer-based terminal, either directly to a card in the S-100 bus, or via an EIA port on the keyboard. From a functional standpoint they are of two types.

One set of specialized input devices enables a physically handicapped person to more easily communicate with the computer. Some have been in use for several years (Brebner and Hallworth, 1976). These include the POSSUM indicator board with suck-puff and other binary controls, and the N.R.C. touch sensitive overlay. Also available are a lightpen and some simple bubble-pad keyboards.

Other specialized input devices are used in order to reduce the amount of coding required to interact with a CAI program. They are of obvious value to persons having a short term memory deficit. A "money" keyboard, for example, has keys which are bills and coins. A trainee may indicate the cost of an item, or an amount of change, simply by touching bills and coins to the amount required: it is no longer necessary to recode from an amount shown on a price tag, to standard keyboard symbols, and to digits on a CRT screen, without any reference to the bills and coins which would be used in a real purchase.

Another special keyboard has keys representing laundry symbols. This is for use with a CAI program written when it was found trainees were damaging clothes owing to an inability to understand such symbols. Yet another keyboard has keys representing food groups, for use with a nutrition program. And a CAI program to teach a sense of time uses a keyboard with three keys only, to represent "Early", "On time", and "Late".

In all these cases, one key is used to represent a set of stimuli, or a set of operations, which the trainee is required to learn as if it is a whole. Since each key is used to provide a symbol for such a set of stimuli or operations, the keyboards may be referred to as "concept keyboards".

Such keyboards are likely to be used much more extensively in the future for CAI with developmentally handicapped persons. However, they may also be used to advantage for CAI in a variety of contexts such as, for example, statistics taught to university students.

Yet another special input device uses a bubble pad keyboard in place of the standard keys of a cash register. This is used with a CAI program to train VRRI clients as cafeteria cashiers.

5. CONTINUOUS RESEARCH AND PRACTICE

Many of the results of CAI research with the developmentally handicapped have been reported following controlled studies carried out at the VRRI and in schools for retarded children and adolescents. Sandals (1973), Strain (1974), and England (1979) have reported on the use of CAI programs to teach money handling and banking skills,

shopping, and budgeting respectively. Eaton (1975) reported on pre-reading programs, and Holz (1976, 1979) on programs to teach social sight vocabulary and beginning number.

It should be noted that a standard procedure in research such as the above has been to use "transfer tests". These are simulations of real life situations, such as a simulated purchase with real articles and money changing hands between a tester on one side of a table and a trainee on the other. The purpose is to obtain a measure of the generalization of learned behavior from the CAI terminal to the situation in which it is intended to be used. More extensive work on such transfer is required, preferably including behavioral observation data, and a follow up of the trainee's progress after graduation from VRRI. In order to meet these and similar needs, a computer-based management system has been designed for an extensive set of data relating to all VRRI trainees, and will be in operation within two months.

The general conclusion from the project is that, provided the programs are written in accordance with what is known regarding their learning, and using appropriate multi-media terminals and special input devices, CAI for the developmentally handicapped is effective. Specific findings from ongoing research are used to effect improvements in the programs. Day to day observations made by the instructors in the Social Education Program are used to the same purpose.

The effect has been to produce an enterprise in which CAI has become institutionalized, in the sense that it forms a solid and expanding base for social education at the VRRI; and an enterprise in which the practical application is continuously informed by ongoing research.

It is a tribute to the VRRI instructors that all concerned have an excellent understanding of what CAI for the developmentally handicapped is, what it can achieve, what are its present deficiencies, and in what directions it can and will be developed in the near future.

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